GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No. E-19-697 GTRI/~~GIT~~ DATE 6 /10 /83

Project Director: Dr. Ste~~v~~phen Antolovich School/~~Lab~~ Chem. Eng.

Sponsor: MARTIN MARIETTA ~~Union Carbide Coroporation~~ SEE RIV I

Type Agreement: Project Authorization 19x-14 under Basic Agreement No. 7802

Award Period: From 7/1/83 To 9/30/84 (Performance) 9/30/84 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated:	$ 30,000.00	$ 30,000.00
Funded:	$ 15,000.00 *	$ 15,000.00

Cost Sharing Amount: $ ______ Cost Sharing No: ______

Title: "Testing LCS Specimens"

ADMINISTRATIVE DATA

OCA Contact ______

1) Sponsor Technical Contact:

V. K. Sikka
Union Carbide Corporation
Nuclear Division
P. O. Box M
Oak Ridge, Tennessee 37830
(615) 574-5112

2) Sponsor Admin/Contractual Matters:

Irene K. Thompson (615) 576-1448
Subcontract Administrator
Purchasing Division
Union Carbide Corporation
Nuclear Division
P. O. Box M
Oak Ridge, Tennessee 37830

Defense Priority Rating: N/A Military Security Classification: N/A

(or) Company/Industrial Proprietary: ______

RESTRICTIONS

See Attached Government Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with Government

COMMENTS:

*Incrementally funded with first $15,000.00 increment to cover period 7/1/83 thru 9/30/83.

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FORM OCA 4:383

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

N-2
~~E~~-668

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 9/19/86

Project No. E-19-697 School/~~Lab~~ Ch E

Includes Subproject No.(s) N/A

Project Director(s) Stephen Antolovich GTRC / ~~GIT~~

Sponsor Union Carbide Corporation

Title "Testing LCS Specimens"

Effective Completion Date: 9/30/84 (Performance) (Reports)

Grant/Contract Closeout Actions Remaining:

Note: Sponsor has all required deliverables per John Schonk.

- [ ] None
- [XX] Final Invoice or Final Fiscal Report w/certification - OCA needs copy.
- [XX] Closing Documents
- [ ] Final Report of Inventions
- [XX] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. Continued by Project No.

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FORM OCA 69.285

FRACTURE AND FATIGUE RESEARCH LABORATORY
Georgia Institute of Technology
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
ATLANTA, GEORGIA 30332
404/894-

November 30, 1983

MEMORANDUM

TO: J. W. Dees, Director

FROM: Stephen D. Antolovich SDA

RE: Progress Report- Oak Ridge - E-19-697

Enclosed is a copy of a type written Progress Report for your information.

A report (hand written) was given to Dr. Sikka some time ago. This was acceptable and no further documentation is required. However we are sending this typed version.

Enclosure

SDA/rt

LOW CYCLE FATIGUE

of

9Cr-1Mo WELDED STEEL

- A Progress Report -

Submitted to:

Dr. V. K. Sikka
Metals and Ceramics Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

Prepared by:

Stephen D. Antolovich
Director, Fracture and
Fatigue Laboratory

Kelly Payne

November 16, 1983

I. INTRODUCTION

New developments in materials technology have indicated that ferritic steels in the 9-12% Cr range have distinct possibilities for replacing the austenitic grades in a number of high temperature applications. Major structural steels such as type 304 and 316 stainless have been shown to be replaceable by a modified composition of a 9Cr-1Mo ferritic steel, particularly in design allowable stresses for temperatures up to 1100°F. Possible applications for these substitutions are mainly in LMFBR steam generators. This steel could become the sole structural component if its properties are optimized. The necessity for welding in these structures is obvious. It is therefore desirable to study these weldments under conditions similar to those experienced in service. Consequently this project is aimed at examining various metallurgical aspects of the LCF properties of a welded 9Cr-1Mo ferritic steel plate.

II. MATERIAL AND BACKGROUND

A microstructural characterization along with microhardness data will be briefly covered in this report, while tensile and LCF bars are scheduled for testing in the next 6-8 months. Updates on this progress will follow as the work proceeds.

A 203 mm thick welded plate made from a modified 9Cr-1Mo ferritic steel was received from ORNL. The plate was submerged arc welded using a standard 9Cr-1Mo composition as a filler metal. ORNL has modified the base material by lowering the Si and increasing the amounts of Nb and V.

The projected time frame for the entire project is approximately 18 months beginning August 1983. A general outline was discussed at a meeting held in July with Dr. Vinod Sikka at the Fracture & Fatigue Research Laboratory, Georgia Institute of Technology. Here the decision was made to perform all testing in the rolling plane of welded plate, 90° to the rolling direction, which traverses the weld face (Figs. 1 and 2). The matrix in Table 1 was set up and will be followed in the initial stages of the project.

Two samples will be run for each condition using a fully reversed, triangular wave form for three total strain ranges of 0.45%, 0.70%, and 1.0%, all at $\dot{\varepsilon} = 4 \times 10^{-3}$ sec $^{-1}$. A tensile testing matrix was set up as shown in Table II.

III. MATERIAL SECTIONING

Two pieces of welded plate received from ORNL are shown schematically in Figs. 1 and 2. Piece 1 is presently being used for microstructural and microhardness data, while piece 2 has been sectioned into plates as shown in Fig. 2. Samples sectioned from these plates are shown in Figs. 3, 4, 5, and 6. Samples 7, 14, 21, 28, 35 and 42 have been machined into tensile bars, while samples 1-4, 8-11, 15-18, 22-25, 29-32 and 36-39 have been machined into LCF bars. Plates 1 and 6 are uncut and will be sectioned pending initial testing results. Each sample sectioned from plates 2, 3, 4 and 5 had dimensions shown in Fig. 7, while final LCF dimensions are seen in Fig. 8.

Machining of the LCF and tensile bars was performed by Wagner & Sons Machine Shop, Inc. in Oak Ridge, Tennessee.

IV. MICROHARDNESS RESULTS

A schematic of piece 1 (plate 7) is shown in Fig. 9, along with relative positions of microhardness traverses presented in this report. Characteristics of Figs. 10, 11 and 12 (traverse #1, 2 and 3, respectively) are high hardness areas (~280 DPH as compared to base values of around 210 DPH) located at the fusion boundary between the base and filler and slight decreases as the HAZ is approached from the base material. Traverse #3 shows a high DPH area in the weld region on the far right portion of the weld. This area crosses a boundary where the two welding sequences overlap, Fig. 16. (The butt portion of the weld is formed) Traverse #5 runs longitudianlly from the crown to the root of the weld, and here again the high hardness region is seen near the root. In addition the hardness increases at low rate to this point. Traverse #4 was used to check variations in the microhardness through the plate thickness, which are evidently very small.

V. MICROSTRUCTURAL CHARACTERIZATION

A section of the entire weld is shown in Fig. 15, and was prepared by etching in 3.5% Nital for 25-30 minutes. A closer look at the weld root and the overlapping pass sequences can be seen in Fig. 16. A micrograph of the standard 9Cr-1Mo weld material is shown in Fig. 17. Generally it consists of long columnar grains which grew perpendicular to the interface between the weld material and the applied surface whether it happened to be the base or the previous weld pass. Also a more equiaxed grain structure was found in the weld region (Fig. 18). This could possibly be due to reheating of selected areas during multiple passing of the electrode. Immediately adjacent to the fusion in the HAZ boundary are large columnar grains due to temperatures in excess of that required for grain coarsening, Fig. 17. Obstructions to grain growth such as AIN are in solution at sufficiently high temperatures allowing these grains to grow to sizes on the order of the prior austenite grain sizes. Adjacent to these grains are small equiaxed regions (Fig. 20) of about the same thickness as the larger grain portion. The heat affected region furtherest from the fusion boundary (Fig. 21) has a small range of microstructures composed varying degrees of bery fine grains and areas which appear to contain relatively densities of carbides. This grain refinement is enhanced of additons of Nb and V. Figure 22 shows the typical grain structure of the modified base material which compares favorably to photomicrographs found in the Advanced Alloy Technology Program March 31, 1983 update.

VI. CURRENT STATUS

Tensile and LCF bars have been machined and are ready for testing. Initial LCF testing will be done at 1.0% and .45% total strain ranges. Plates #1 and #6 will be sectioned and made into specimens after initial results are obtained, while a more detailed study of microstructure and microhardness will continue. We anticipate that some transmission electron microscopy (TEM) studies will also be carried out and results should be available by spring of 1984.

Table I. L.C.F. Test Matrix

	Number of Specimens		
Temperature	Base	Weldment	Weld
25°C	6	6	6
593°C	6	6	6

Table II. Tensile Test Matrix

	Number of Specimens		
Temperature	Base	Weldment	Weld
25°C	1	1	1
593°C	1	1	1

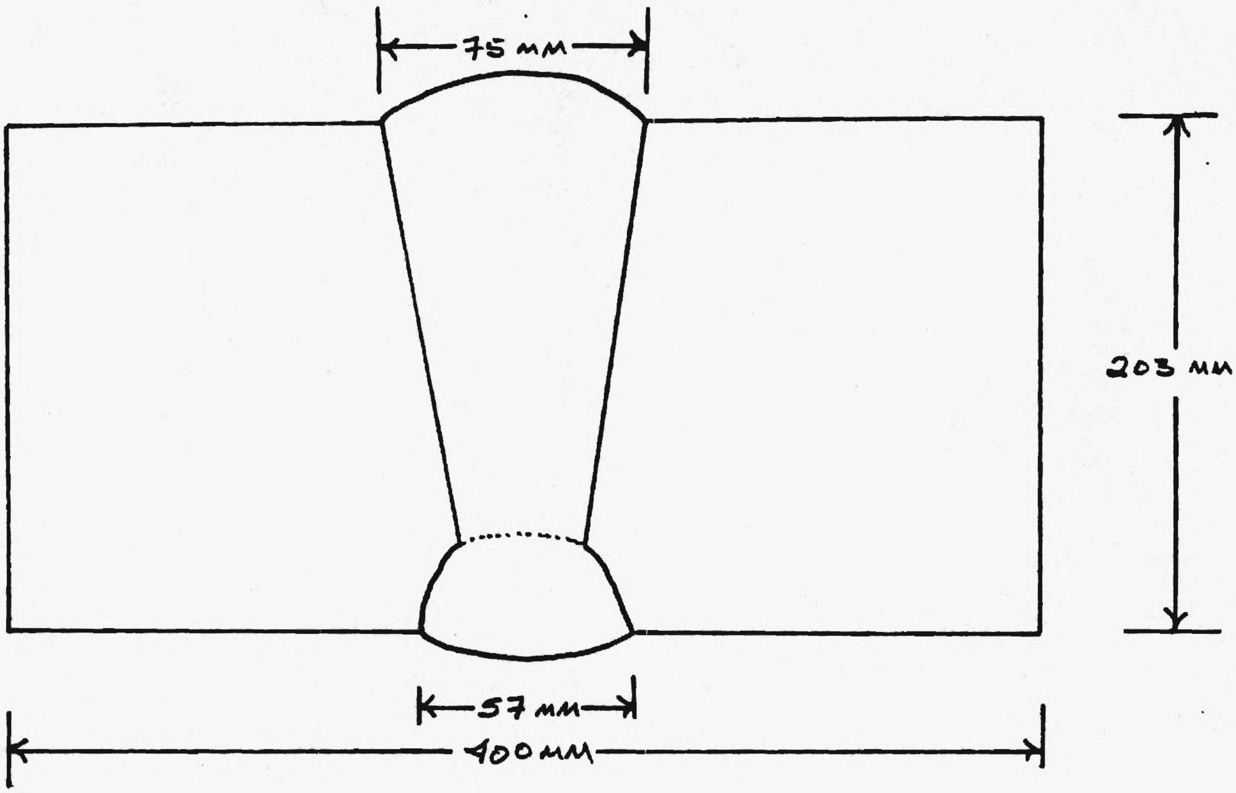

Fig. 1. Schematic of piece #1 (plate #7) from ORNL (thickness = 14 mm)

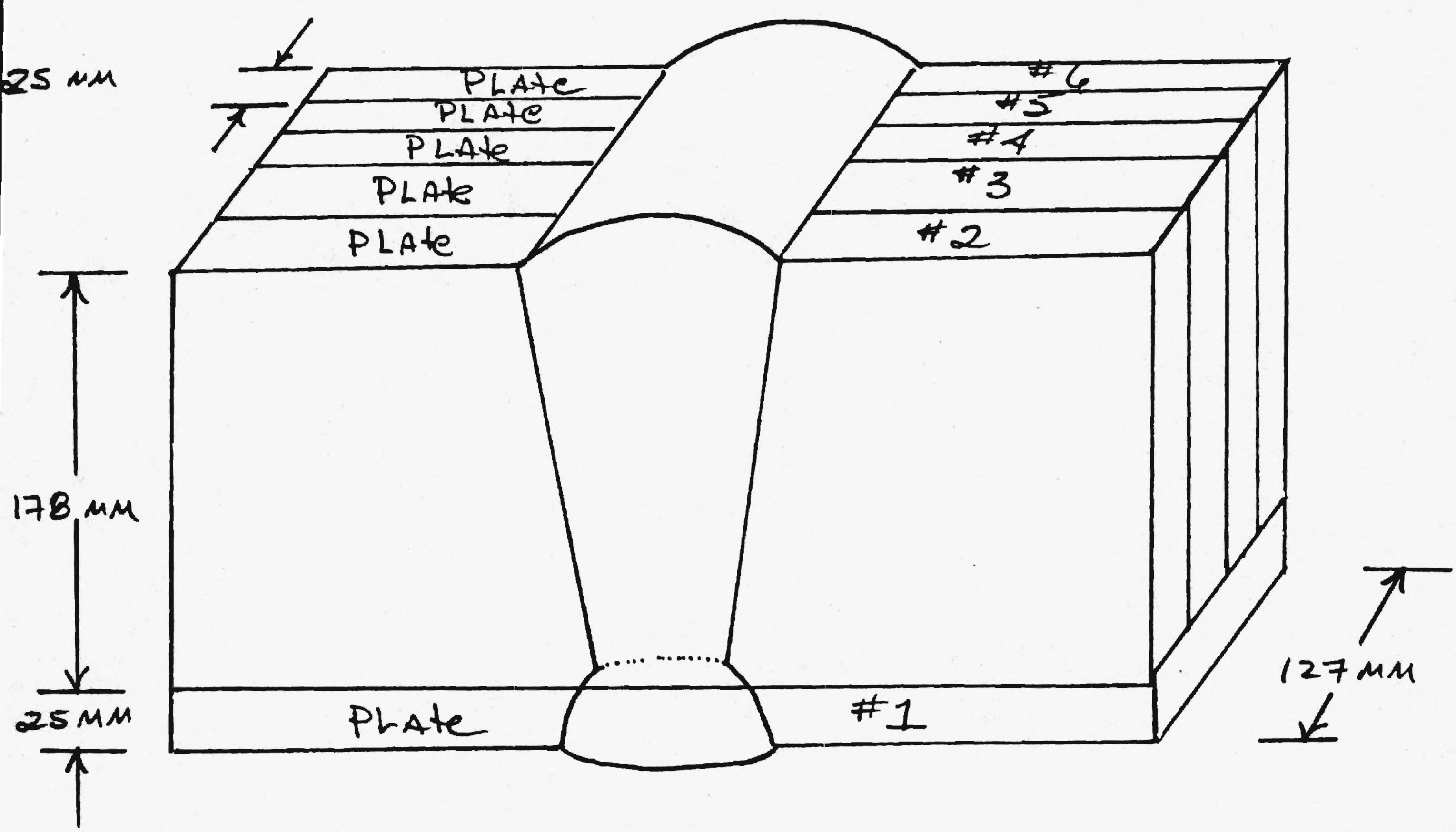

Fig. 2. Schematic of piece #2 (Plates 1-6) received from ORNL.

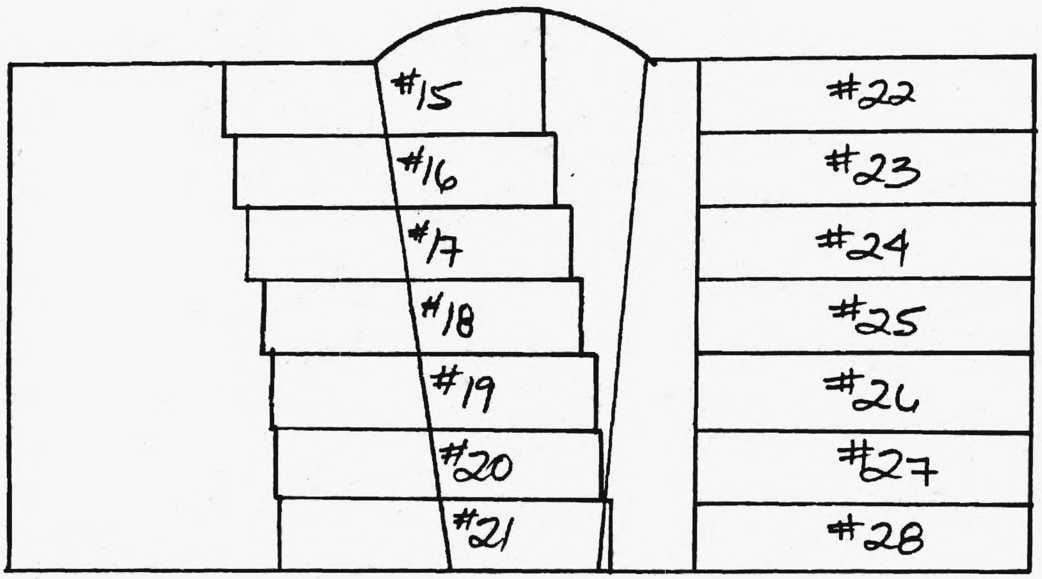

Fig. 5. Samples sectioned from plate #3, samples #15-28. Note that gage section of the samples 15-21 contains all microstructural features while specimens 22-28 are taken from the base metal.

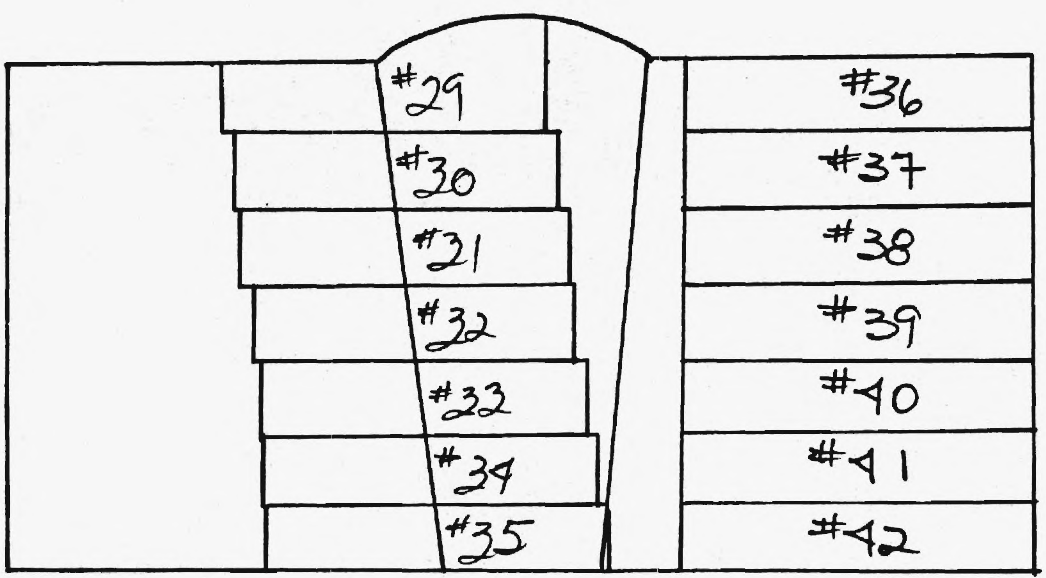

Fig. 6. Samples sectioned from plate #4, samples #29-42. Note that gage section of the samples 15-21 contains all microstructural features while specimens 22-28 are taken from the base metal.

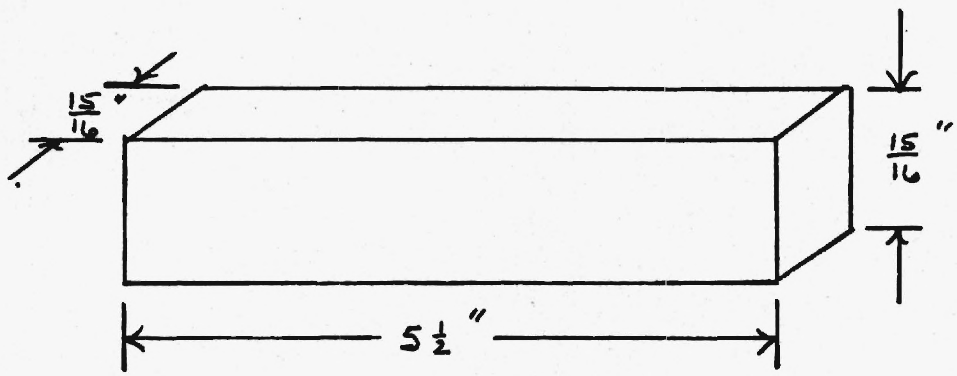

Fig. 7. Sample dimensions cut from plates.

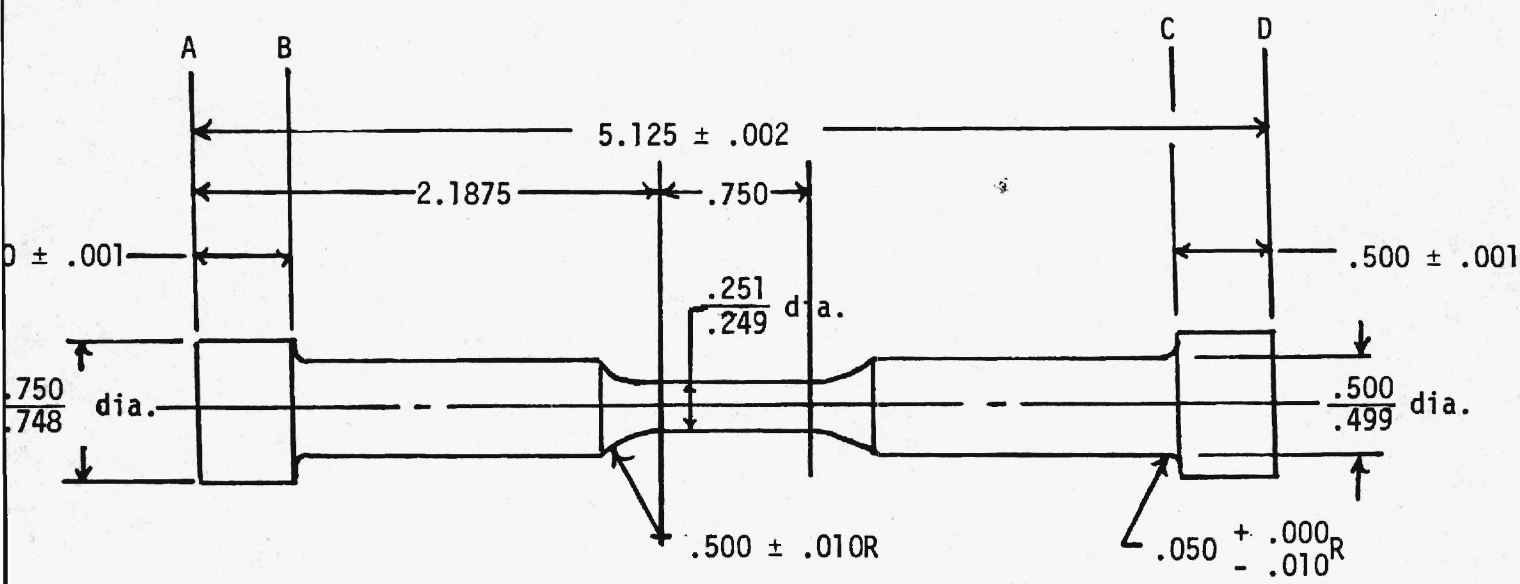

Fig. 8. Final LCF sample dimensions. Surfaces A, B, C and D are parallel within .001 inch.

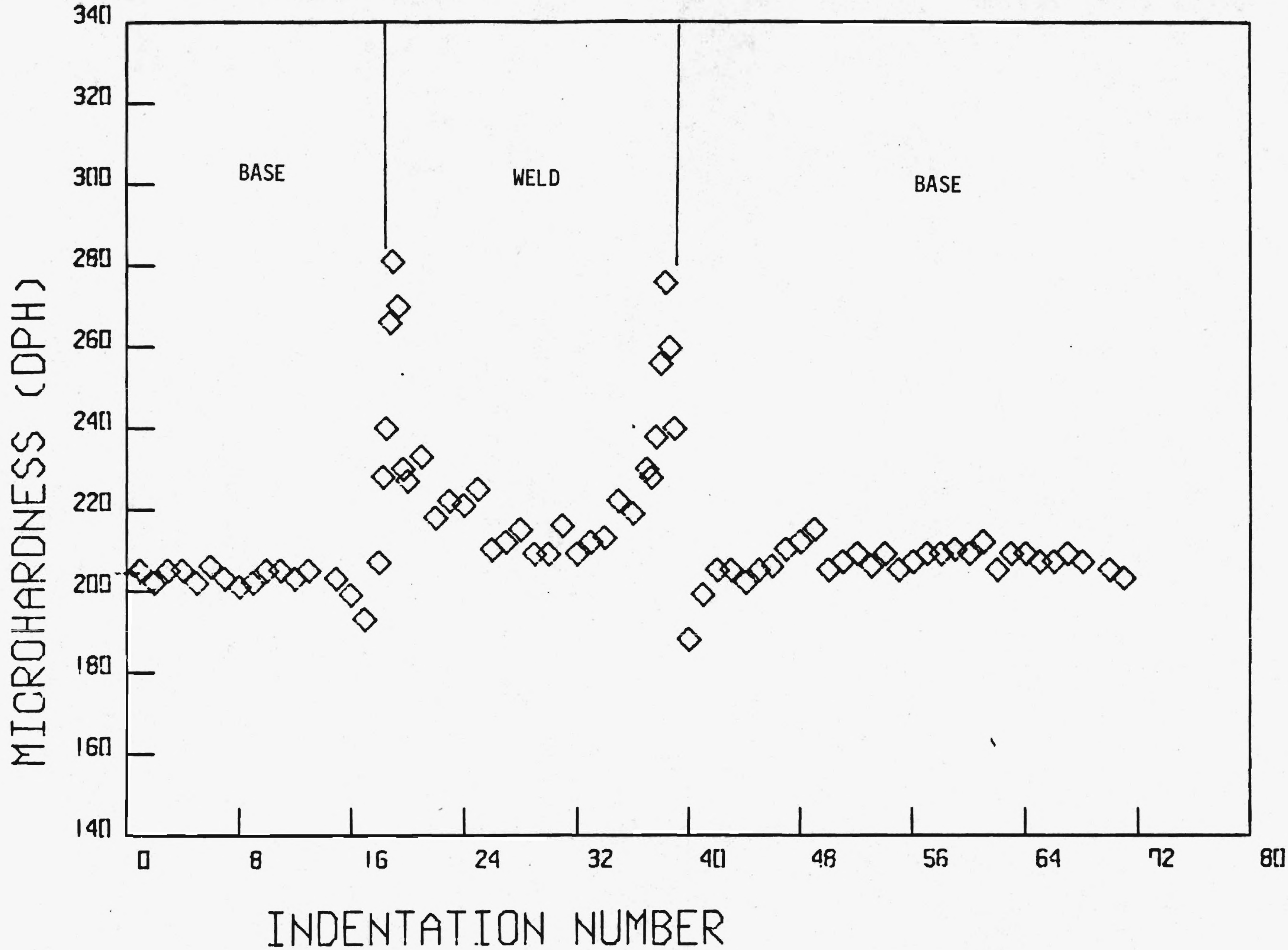

Figure 10 SPECIMEN # 7 / TRAVERSE # 1
1 INDENTATION UNIT = 0.25 CM (SPACING)

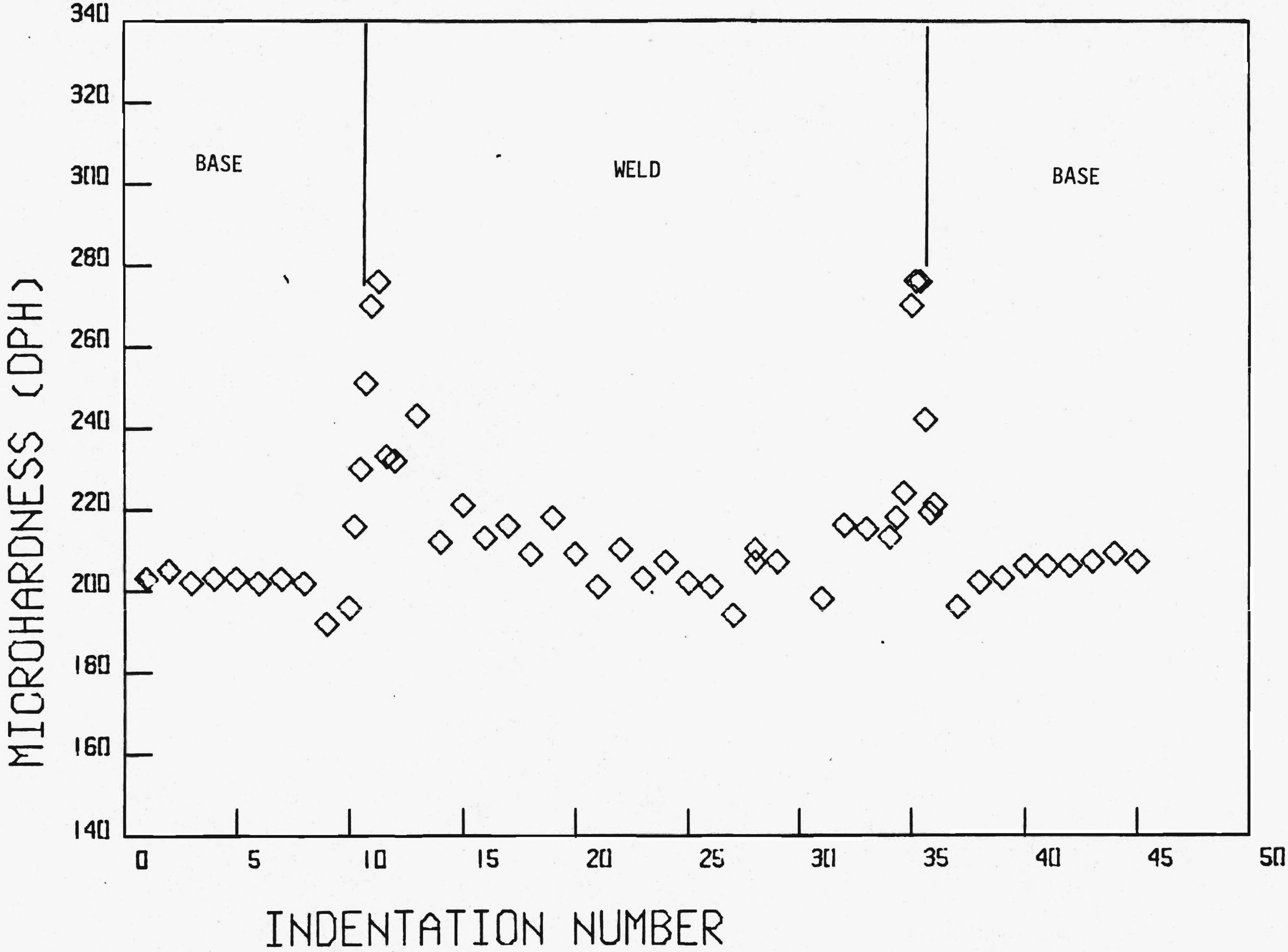

Figure 11 SPECIMEN # 7 / TRAVERSE # 2
1 INDENTATION UNIT = 0.25 CM (SPACING)

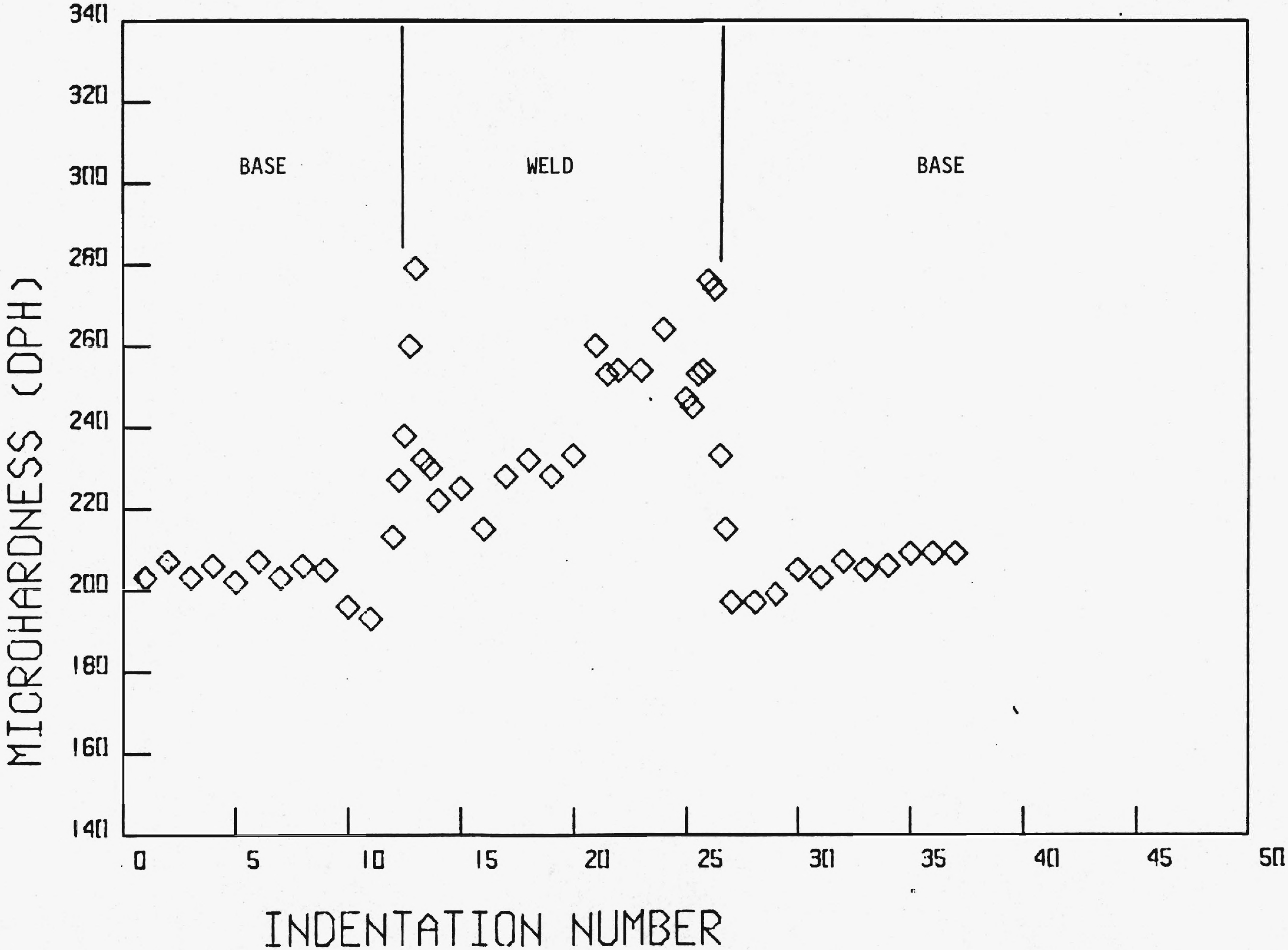

Figure 12 SPECIMEN # 7 / TRAVERSE # 3
I INDENTATION UNIT = 0.25 CM (SPACING)

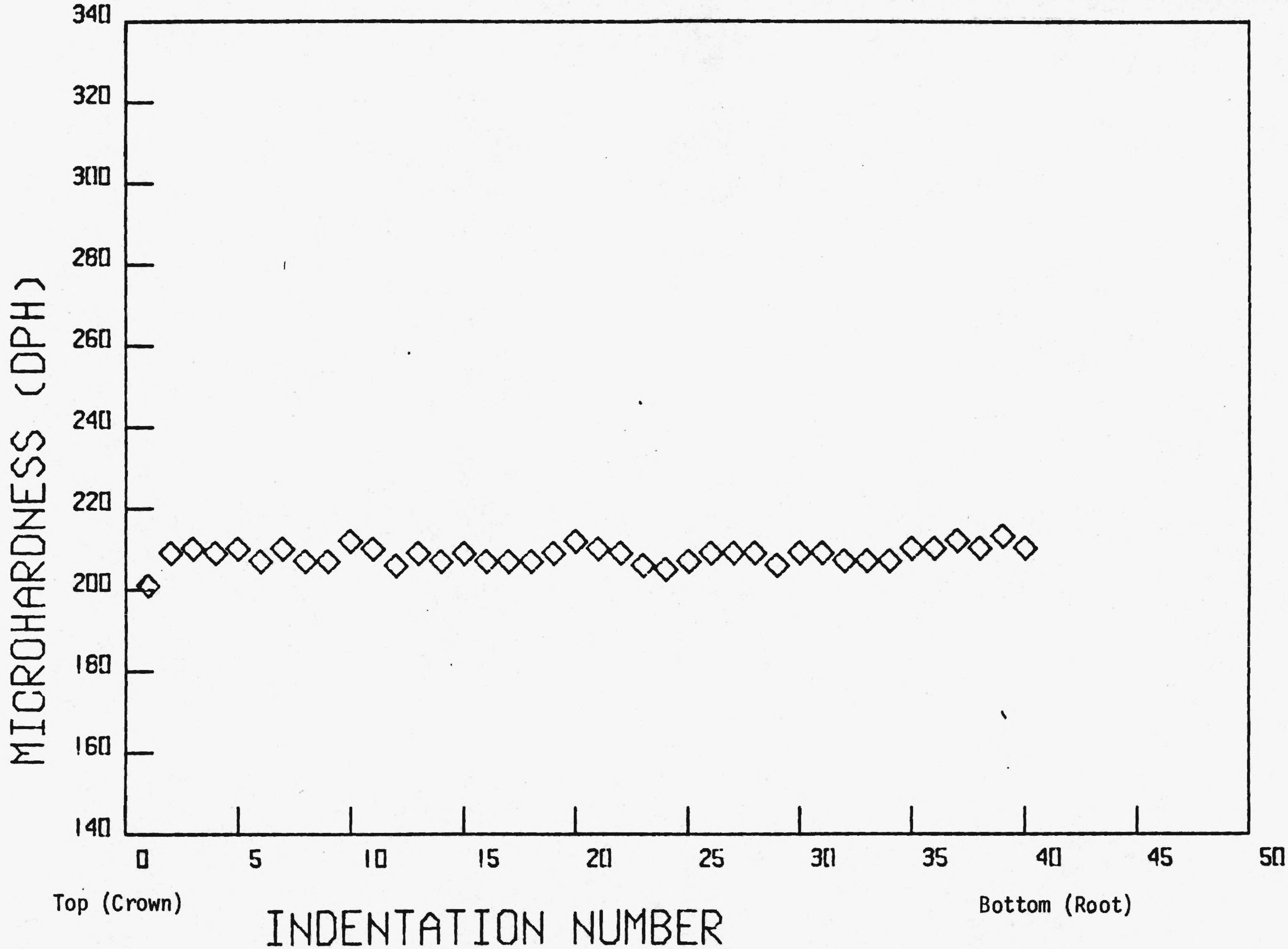

Figure 13 SPECIMEN # 7 / TRAVERSE # 4 Hardness of base metal from top to bottom
1 INDENTATION UNIT = 0.50 CM (SPACING)

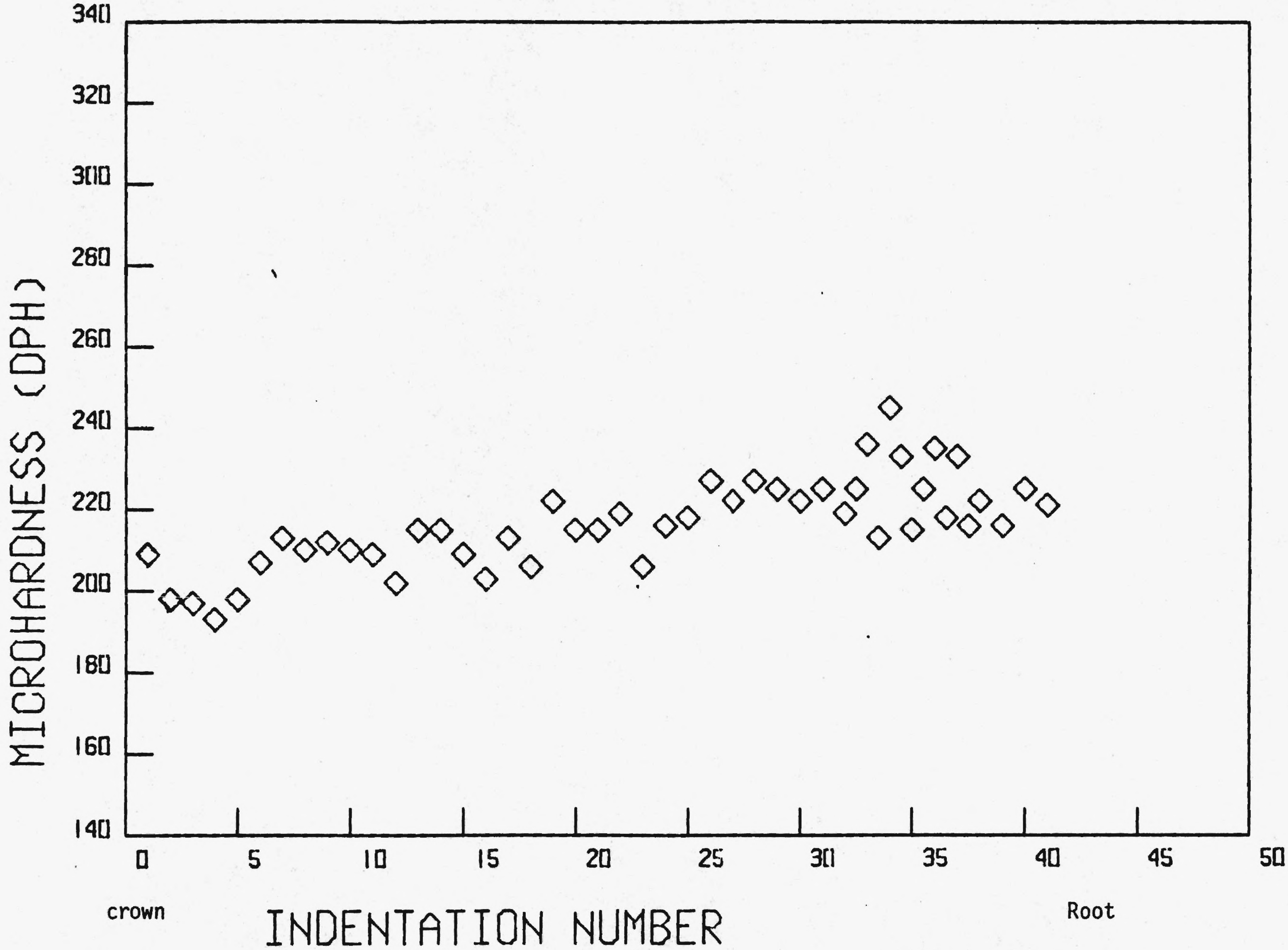

Figure 14 SPECIMEN # 7 / TRAVERSE # 5 Hardness of weld metal from crown to root.
1 INDENTATION UNIT = 0.50 CM (SPACING)

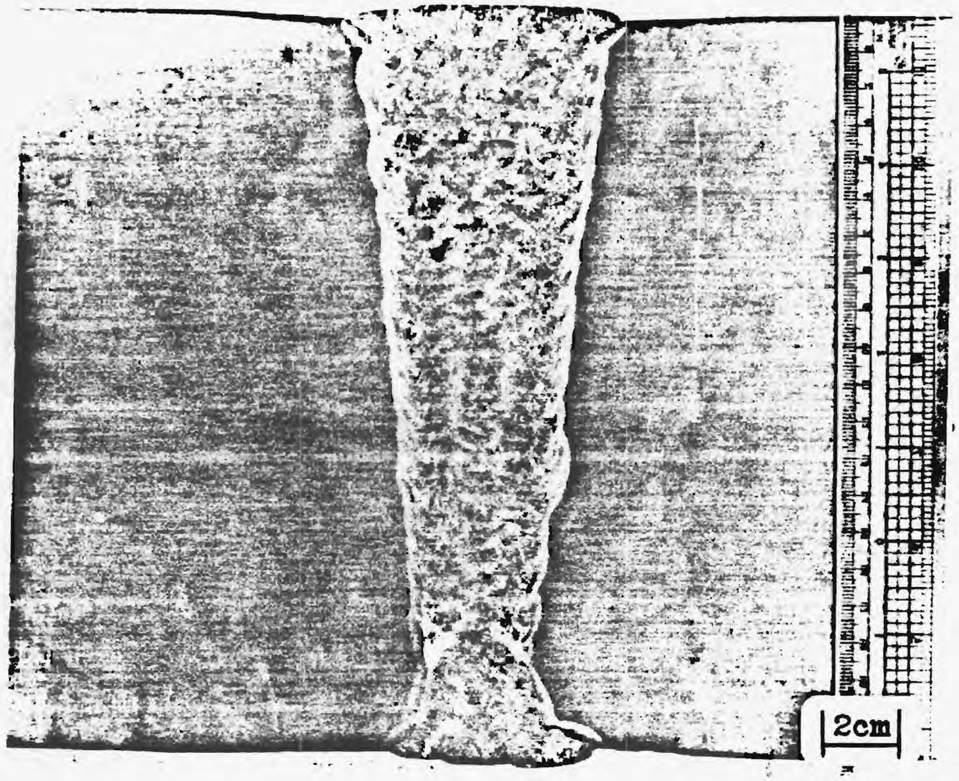

Fig. 15. Macrograph of complete weld in 203mm thick plate

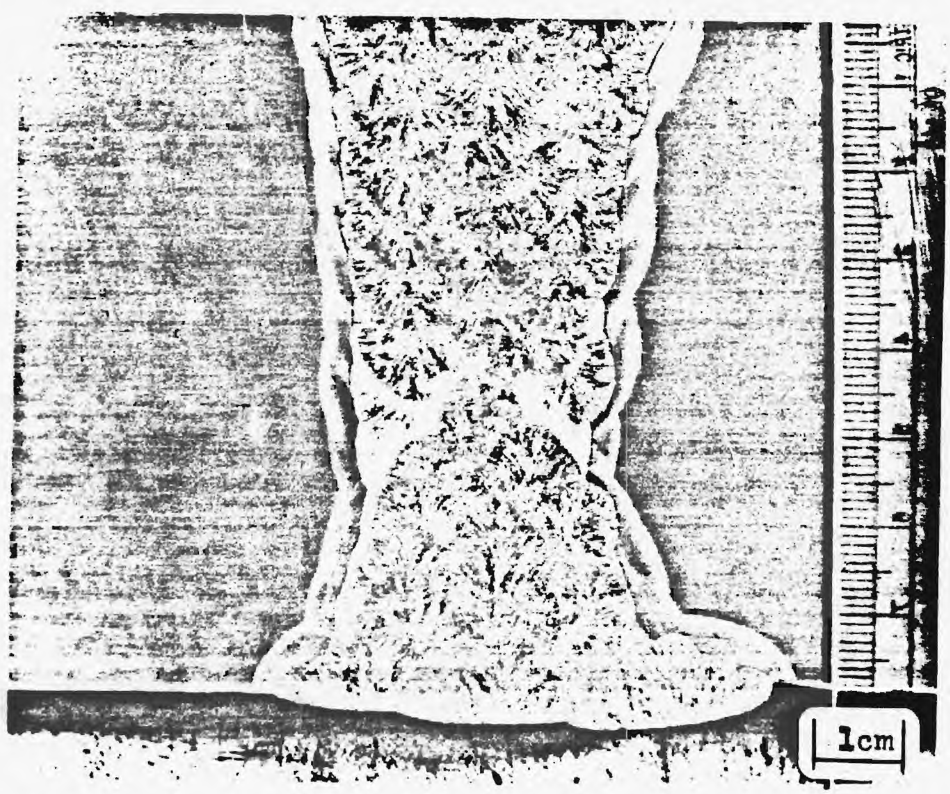

Fig. 16. Macrograph of lower half of weld in Fig. 15

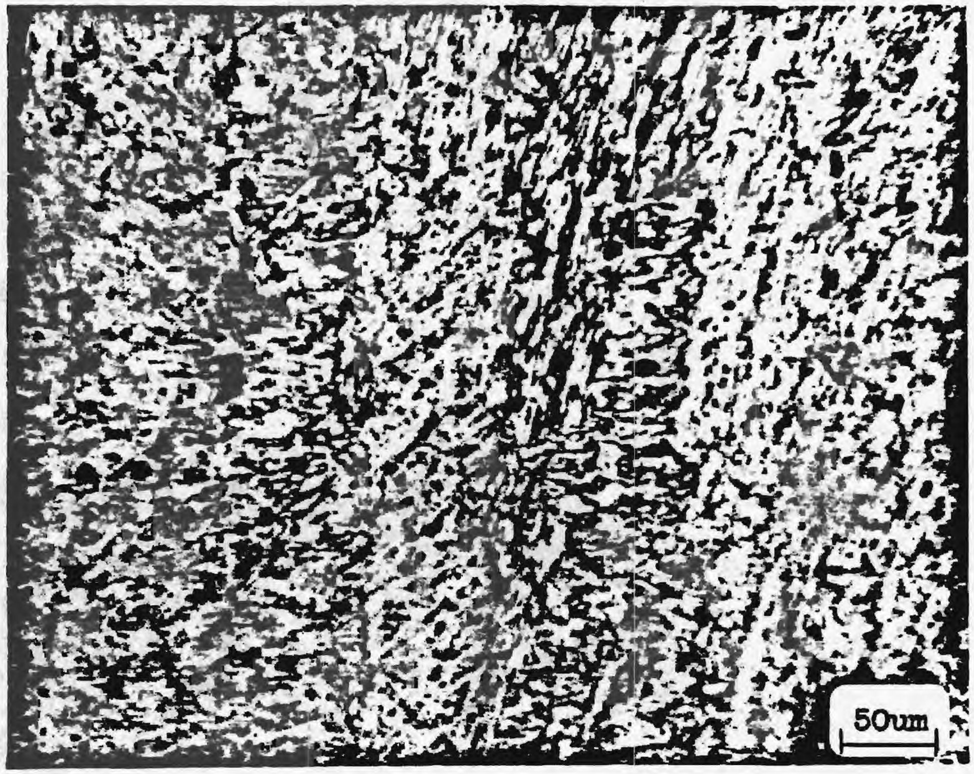

Fig. 17. Columnar weld zone (250x)

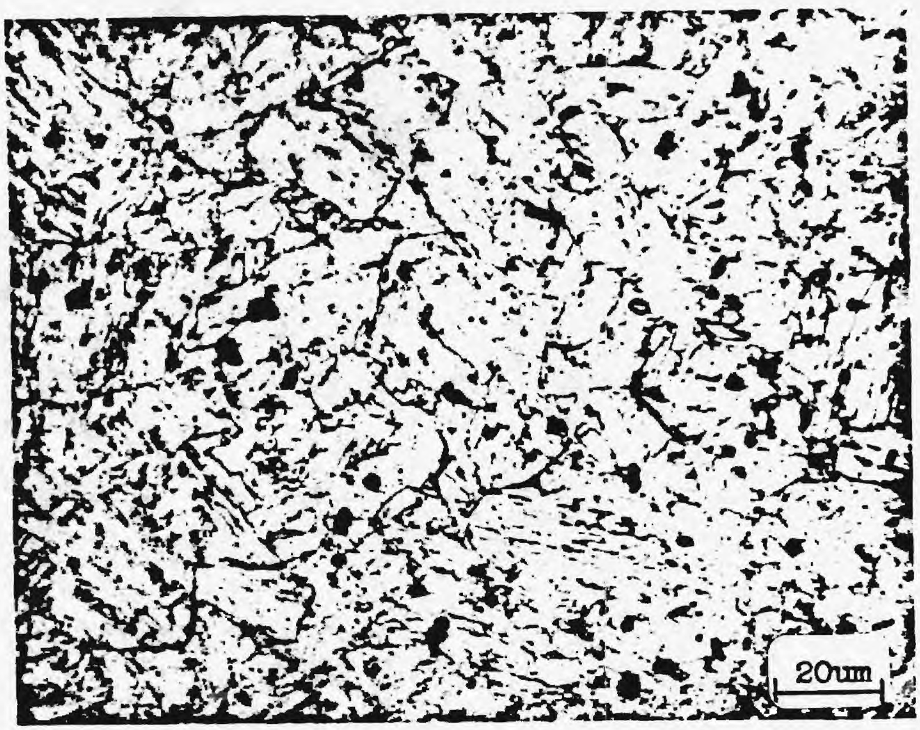

Fig. 18. Small equiaxed weld zone (690x)

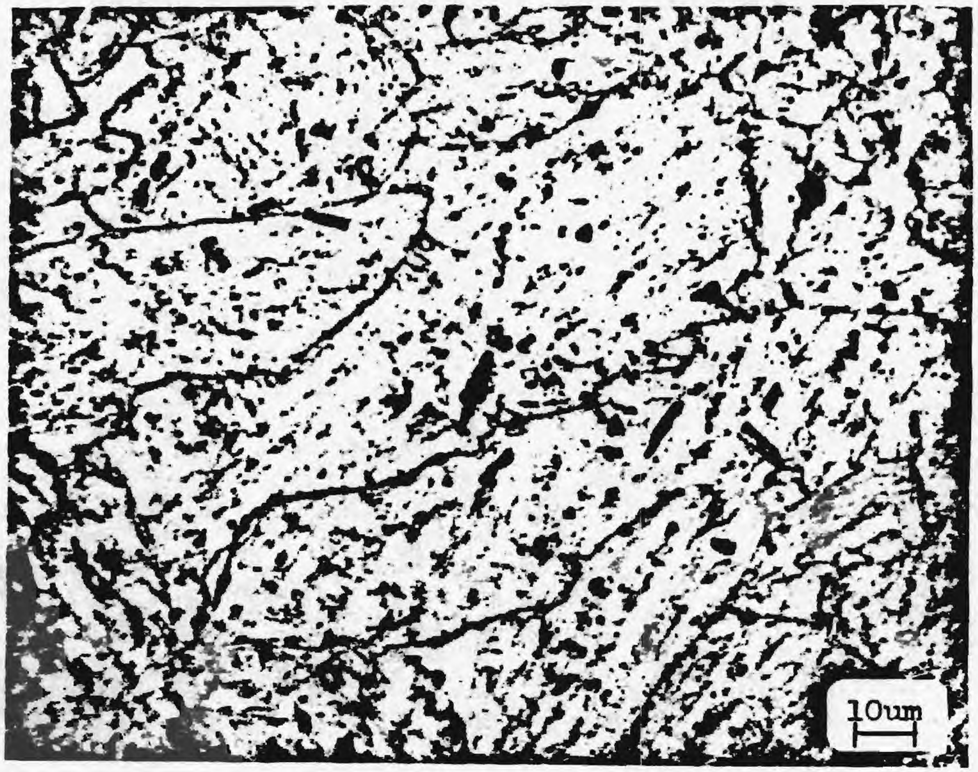

Fig. 19. Large grain adjacent to weld (780x)

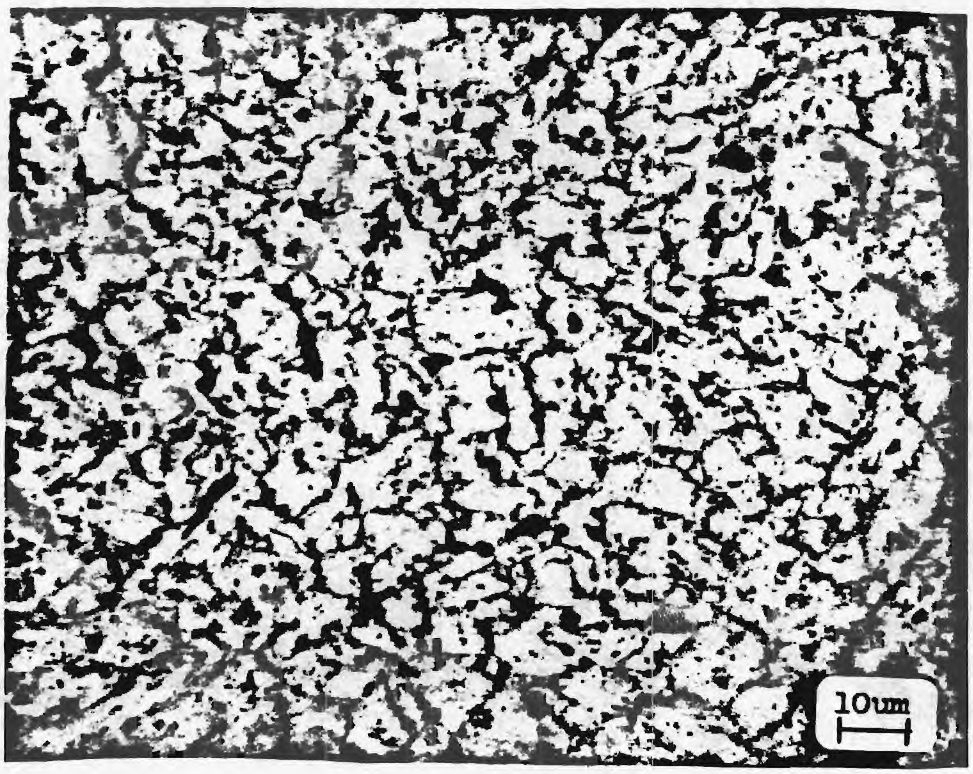

Fig. 20. Small grain adjacent to large grain (830x)

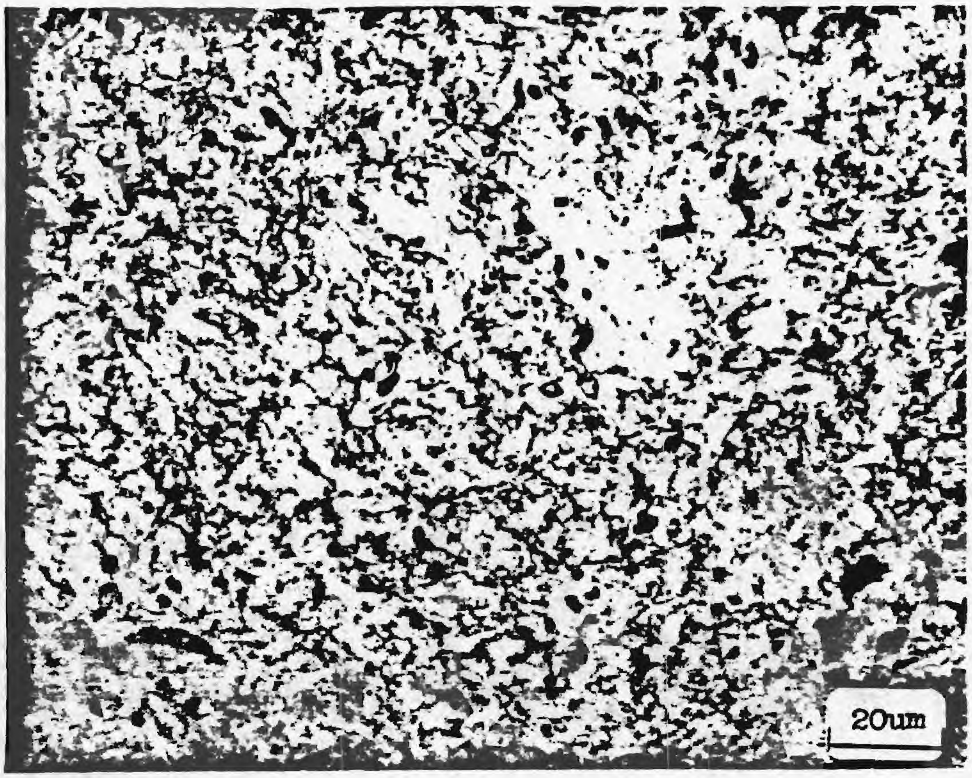

Fig. 21. Grain refined region adjacement to small grane (700x).

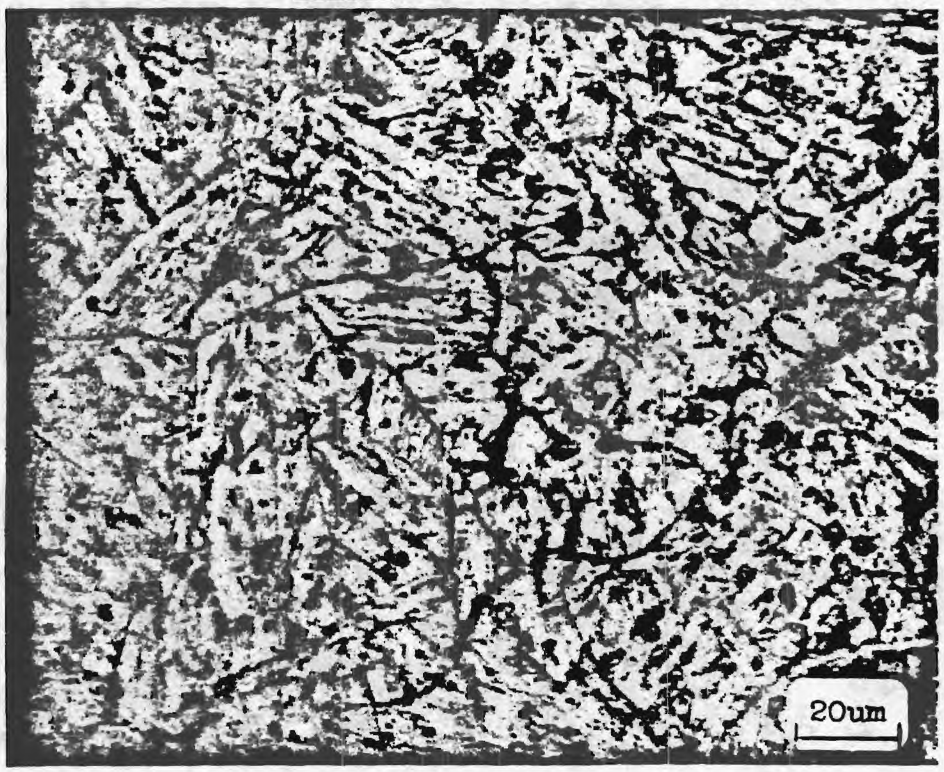

Fig. 22. Base material (750x)